Decimetre-level Positioning System for Hydrographic Applications

Fugro has introduced a new service called Fugro High Performance (HP) with design goal of 0.2m 95 per cent horizontal and 0.3m 95 per cent vertical. Both monitoring data and field results are presented showing a performance well within these criteria. This new high accuracy service has expanded the applications for real-time DGNSS in both static and mobile environments. One such application is real-time tidal measurements through accurate height determination of an offshore survey vessel.

In recent years various applications have emerged in offshore and land environments requiring decimetre accuracy real-time positioning. This level of accuracy has been either impossible or prohibitively expensive to achieve over wide areas with the existing real-time GPS positioning techniques.
Differential GPS is an established technique that provides metre-level accuracy real-time positioning. The differential GPS systems typically use single frequency L1 code pseudo-ranges differenced between the rover and reference station. The accuracy of single baseline DGPS decreases as the distance from reference stations increases, because of the influence of the tropospheric, ionospheric and orbit errors. Various techniques have been developed to improve the accuracy of single baseline DGPS. Nevertheless, positioning accuracy of DGPS is limited to the sub-metre accuracy level because of fundamental limitations due to GPS pseudo-range noise and multipath.
Real-Time Kinematic (RTK) is another relative positioning technique that can potentially provide centimetre-level accuracy positioning. The RTK technique, requires however, a distance to the closest stations not to exceed several tens of kilometers. Because of these distance limitations, the RTK technique is not suited for offshore or wide area coverage.
A new decimetre-level accuracy system developed by Fugro, bridges accuracy and coverage gaps between a small area centimetre-level RTK and a wide area metre-level DGPS. The system is a result of several years of Fugroâ€™s in-house research and development. The new service, named Fugro-HP (High Performance) Service, complements other geostationary satellite-based Fugro DGPS positioning services and opens potential new applications.

Some Hydrographic Survey Challenges
Absolute positioning of the seabed, features on the seabed or in the water column, uses the surface position as the starting point. The accuracy of this position will contribute to the total accuracy.
Horizontal positioning is now possible to the decimetre-level, globally. The growing community that requires such accuracy can today use GPS-based services to obtain this.
Vertical positioning is more complex, and the measurement is influenced by several physical variables. The main ones are: tide, atmospheric pressure, water salinity, waves, currents, swell and vessel squat. All these variables are contributing to the error budget of the measurement, and it adds cost to the projects.
MSL (Mean Sea Level) and LAT (Lowest Astronomical Tide) are the most used vertical datums today. The zero level of such datums are not easily established offshore where practical fixed reference points are absent. This makes repeated depth references uncertain. As most measuring instruments get better, the uncertainty of the zero level of the vertical datum plays a more and more important role in the error budget. This is particularly true at offshore sites.
Practical problems with establishing the best MSL or LAT based depths, are connected to use of several types of measuring equipment (tide gauge, barometer, salinity profiler, and motion sensors). These measurements and the associated processing is time consuming and costly. In addition, they all introduce an element of uncertainty. Real-time operations which need the highest accuracy are therefore often not possible.
A new vertical datum based on the available highly accurate GPS-based services is now possible as the vertical accuracy in many regions (at least offshore) is much better than the best established MSL or LAT. Using the GPS ellipsoid as the vertical reference surface will give real-time accurate positions in 3D. Referring all depths to a mathematical surface like this will make the data independent of whatever MSL changes that might take place in the future.
It is not practical to have maps and other depth-based products operating with ellipsoid depths. However, if the measured points are in that datum, it is a simple mathematical conversion to transform the depth to more practical and â€˜humanâ€™ vertical datum, like the MSL. In this process it will be an important task to make a depth model where the MSL is given in ellipsoid heights. The same should be made for other datums of interest (e.g. LAT). The MSL depth is then found by:

DepthMSL = MSLEll - HeightEll

The main advantage is to have all basic data in a mathematically well defined reference system, and be able measure the 3D position in this system in real time. Such data measurements will lead to consistent datasets even when different surveys are put together.
An interesting side effect is that recording platforms (vessels, buoys etc.) can monitor temporary changes in the sea level at one place and by comparing it to the ellipsoid provide the local variations.

Fugro High Performance (HP) Service

The new service uses dual-frequency observations in a network mode to provide a decimetre-level positioning solution. Using dual-frequency measurements eliminates the influence of the ionosphere. Unlike standard DGPS systems, which use pseudo-range code observations, this high accuracy system exploits the high precision of carrier phase observations to achieve higher accuracy positioning solutions.
The HP service was introduced in May 2001. The high precision service complements current code-based DGPS services provided worldwide by Fugro. The coverage map of the reference stations and the geostationary satellite broadcast footprints is shown in Figure 1. The HP service now covers North America, Brazil, most of Europe, the Persian Gulf, and extended areas in the Far East.

Hp Monitoring Results

Figure 2 shows a network solution on 24 April 2002 where the mobile is at Rogaland in South West Norway. The reference stations around the North Sea are used with Aberdeen at 490 km being closest. The errors are well within the specification of 0.2 m 95 per cent horizontal and 0.3 m 95 per cent height.
The plot shows the error in East, North and height for a 24-hour period. The dotted lines are Â±0.2m in East/North and Â±0.3m in height and are shown for reference. On top of each plot the statistics (mean and standard deviation) are given. Each plot contains about 77,000 data points.
In order to ensure that the mobile gets corrections for all satellites which it sees, using reference stations surrounding the mobile is optimal. Even with very long baselines to the reference stations, high accuracy is achieved.
Table 1 shows a summary of monitoring results. This includes data from a network solution where the baselines are 1,150 to 1,920 km. The second from last column is the horizontal 2dRMS error (two times the root sum square of the mean and standard deviations in North and East). This is an approximation for the 95 per cent horizontal error. The last column is the 95 per cent height error (given by two times root sum square of the mean and standard deviation in height). It is seen that both the solutions are well within the HP specification of 0.20 m 95 per cent horizontal error and 0.30 m 95 per cent height error.

Applications

The most important use of the HP service to date is for applications where the height of a vessel needs to be accurately determined.

- CSHel = Calm Sea Height (ellipsoid) (Depending on air pressure etc)
- OT = Observed Tide
- MSSel = Mean Sea Surface (ellipsoid)
- Gel = Geoid Height (ellipsoid)
- Hel = Vessel Reference Point Height (ellipsoid)
- Hpel = HP antenna Height (ellipsoid)
- AVO = Average Vertical Offset between Calm Sea and Predicted Tide
- PT = Predicted Tide

Figure 3 shows the relationships between the various variables. If everybody were using Ellipsoid Height, there would be no problem, as this is what the HP system generates. This will probably become the preference in the future giving a unique height reference which is stable over time.
Often the heights need to be referenced to a Mean Sea Level, and then the tidal variations need to be accounted for. Using HP, this can be done in real time by using a predicted tide model (it does not need to be very accurate as it is calibrated by HP measurements) and calculating an Average Vertical Offset (AVO).
Figure 4 shows data collected by Petroleum Geo Services (PGS) on a 3D seismic survey off the coast of mid Norway on a project for the Norwegian oil company Statoil. The dark curve is the raw HP measurements with the heave movements due to waves which look like noise.
The predicted tide and calculated tide based on HP measurements are also shown. The difference is seen to be varying slowly and can be accurately estimated, smoothing the raw data. Fugro is developing a software package which does these calculations in real time.
It should also be noted that the measured velocity of the HP service is very accurate. This can be used in e.g. gravimetric surveys in order to remove the influence of host vehicle movements on the quality of the gravimetric data.

Surveys with Ellipsoid Datum

In 1999 Statoil performed a large (600km2) bathymetry survey at the Troll field (approximately 350 metres of depth). One purpose of the survey was to establish a reference seafloor model for the future. One reason for this was to be able to monitor seabed subsidence over the coming 50 years. To reduce as many uncertainties as possible the ellipsoid was selected as the vertical datum. At that time RTK was the only system that could give the needed coverage from a reference station placed on the Troll platform. The data was acquired and processed by Fugro, and all DTMs and maps were made in this datum (Figure 5). Today it is possible to do similar surveys anywhere offshore, independent of having a local reference station.

Summary

The Fugro HP carrier-phase based high accuracy service has been in operation since May 2001. The service is now operational in the Americas, Europe, Middle East and the Far East. Monitoring of the performance shows that the specified accuracy of 0.2m horizontal (95 per cent) and 0.3m vertical (95 per cent) are met with good margin. This is also true using single baselines approaching 1000 km, and for network solutions with baselines well above 1,000 km.
An important application of the Fugro HP service is to accurately determine the height of a vessel. This provides a repeatable height reference relative to the ellipsoid and can be used to determine tidal variations.
To achieve consistent datasets from different surveys, and to make a seamless dataset, the establishment of a mathematical reference surface for 3D positioning is of vital interest. In addition to this principal importance, the survey companies, and their clients, will save much on the cost side. For the error budget, such a vertical datum will remove several of the contributions from todayâ€™s methods. This is due to fewer instruments and sources of errors, as well as the datum zero level.
